New hydraulic gallery to improve operation conditions at the Emosson hydro scheme

Nima Nilipour, Michel van Mark, Azin Amini
BG Consulting Engineers Ltd, LCH-EPFL
Lausanne
Switzerland

Patrick Monnay
Electricite d'Emosson SA
Martigny
Switzerland

Introduction

A new hydraulic gallery was constructed to increase operational resilience and mitigate risks of Emosson hydropower scheme in the Swiss-French Alps.

One of the main constraints of the operation is to avoid the overflow of the so called "Corbes" surge chimney during pumping, if the upstream valve is closed. While this scenario is very rare and happened only three times since the commissioning of the dam in 1973, it is considered as a critical issue for operation of the scheme due to the high risk of this event. Different solutions have been studied to avoid the overflow of the surge chimney. However, The safest solution was to create a new gallery bringing water from the top of the surge chimney to the Emosson Reservoir. However, the execution of the new so-called "Corbes" Gallery took place in challenging alpine conditions with difficult access and a very tight schedule

1. Background

Electricité d'Emosson, a French-Swiss Joint Venture owned in equal shares by Alpiq and EDF, collects water from the Mont Blanc Massif to the Emosson Reservoir at 1930 masl. Emosson Dam was constructed from 1969 to 1973 and submerged on its upstream the Barberine Dam, owned by the Swiss Federal Railways, under 42 meters of water.

The water coming from the high valleys of the river Arve and Eau Noire in France, and from Val Ferret and Trient Valley in Switzerland, is brought to the reservoir by three headrace tunnels. Through the South and West collectors located on the French side, the water is routed to the artificial lake by gravity. The water from the Swiss side arrives through the Eastern gallery; after passing through the compensation basin of the Esserts, the water is pumped at Vallorcine power station to Emosson, see Figure 1.

With a mean gross head of 1400 m, the average total annual energy production of the upper and lower cascades at Emosson-Vallorcine and Le Châtelard-La Bâtiaz is around 800 GWh.

Depending on the water level in the Emosson reservoir, it can absorb a great part of the rainfall and thus reducing the effect of floods downstream. Therefore, the Emosson reservoir plays an important role of protection against floods occurring in the Rhone valley. However, the rivers on the downstream of the dams and the water intakes are likely to carry considerable risks. Large quantities of water may be suddenly released into the riverbeds, especially in the case of flushing the compensation basins or gravel and sand traps; or after a sudden shutdown of the power plants. In order to avoid the dam or intakes overtopping, the spillway gates open automatically. Such operations can provoke a sudden unexpected and temporary rise of water flow. Within a few minutes, the level and the discharge of the river significantly increase, and the water carries along materials piled up in the riverbed in dry period; this represents a high risk to anyone staying in the riverbed. Warning signs have been displayed in the affected zones. They alert hikers, fishermen and canyoning fans not to stay in the river, since the calm and regular flow of the water may prove to be fatally misleading. Regular and thorough inspections are performed in order to ensure the timely detection of any events threatening the safety of the installations. Special alarm systems (flood-alarm sirens) have been installed in the zones with flooding risk.

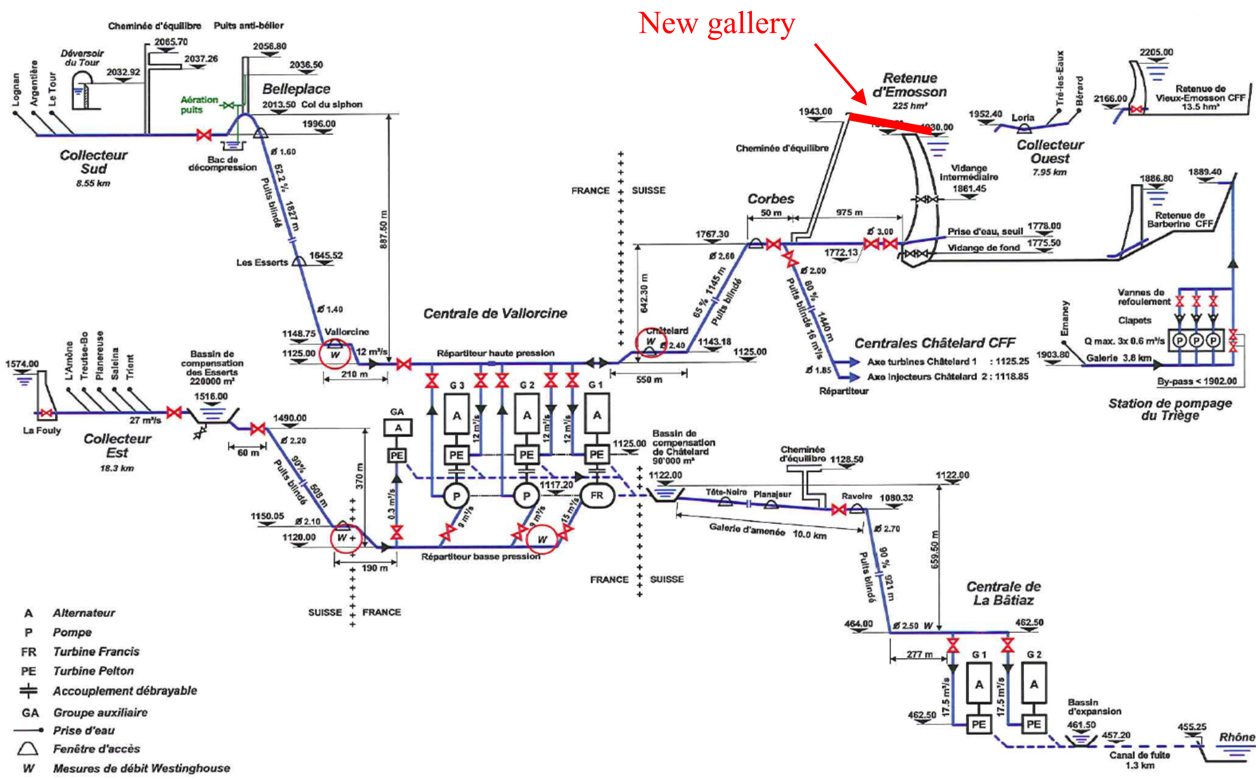

Fig. 1. Hydraulic system of Emosson hydropower scheme

One of the constraints of the operation is to avoid the overflow of the so called "Corbes" surge chimney during pumping, if the upstream valve is closed. While this scenario is very rare and happened only three times since the commissioning of the dam in 1973, it is considered as a critical issue for operation of the scheme due to the high risk of this event. Different solutions have been studied to avoid the overflow of the surge chimney. The adopted solution was to create a new gallery bringing water from the top of the surge chimney to the Emosson Reservoir.

2. Main alternatives

The surge chimney overflow happens when the upstream gate is closed combined with a safety automation fault of the pumping. In case of a safety automation fault of the downstream gate of the South Headrace gallery as well as the automatic shutdown of Vallorcine and Châtelard pumping stations, water level will raise in the pressure shaft and since the upstream gate is closed, it will overflow at the top of the Corbes surge chimney. Despite safety equipment redundancy, there is still a residual risk and the only solution is to shut down the pumps manually, which could take up to 30 minutes in case of remote operation of the powerhouse.

During this time, the overflow discharge of maximum 40 m^3/s can flood the Barberine canyon with very high risk for potential tourists and canyoners in this zone.

In the preliminary stage of the project, different solutions had been studied to mitigate the risk of overflow in the Barberine River, as follows:

- Maximizing the reliability of the automation system in order to guarantee the safety of operation in all circumstances
- Creating a storage volume in the Barberine River avoiding flooding the downstream zone
- bringing water from the top of the surge chimney to the Emosson Reservoir through a new gallery
- Heightening the surge shaft in order to avoid water release to the Barberine River

A multi-criteria analysis was carried out using the following criteria: environmental impact, cost, geological risks, schedule, equipment safety, concomitant and residual risk, technical difficulties and finally operation interruption. Based on this analysis, the alternative of a bringing water from the top of the surge chimney to the Emosson Reservoir through a new gallery, has been adopted as the best solution.

The new gallery has a section of 13.3 m^2 with a length of 483 m. The average longitudinal slope is 1.6% and the exit point is at 1932 masl, which is 2 m above the maximum normal level of the Emosson reservoir as seen in Figure 2.

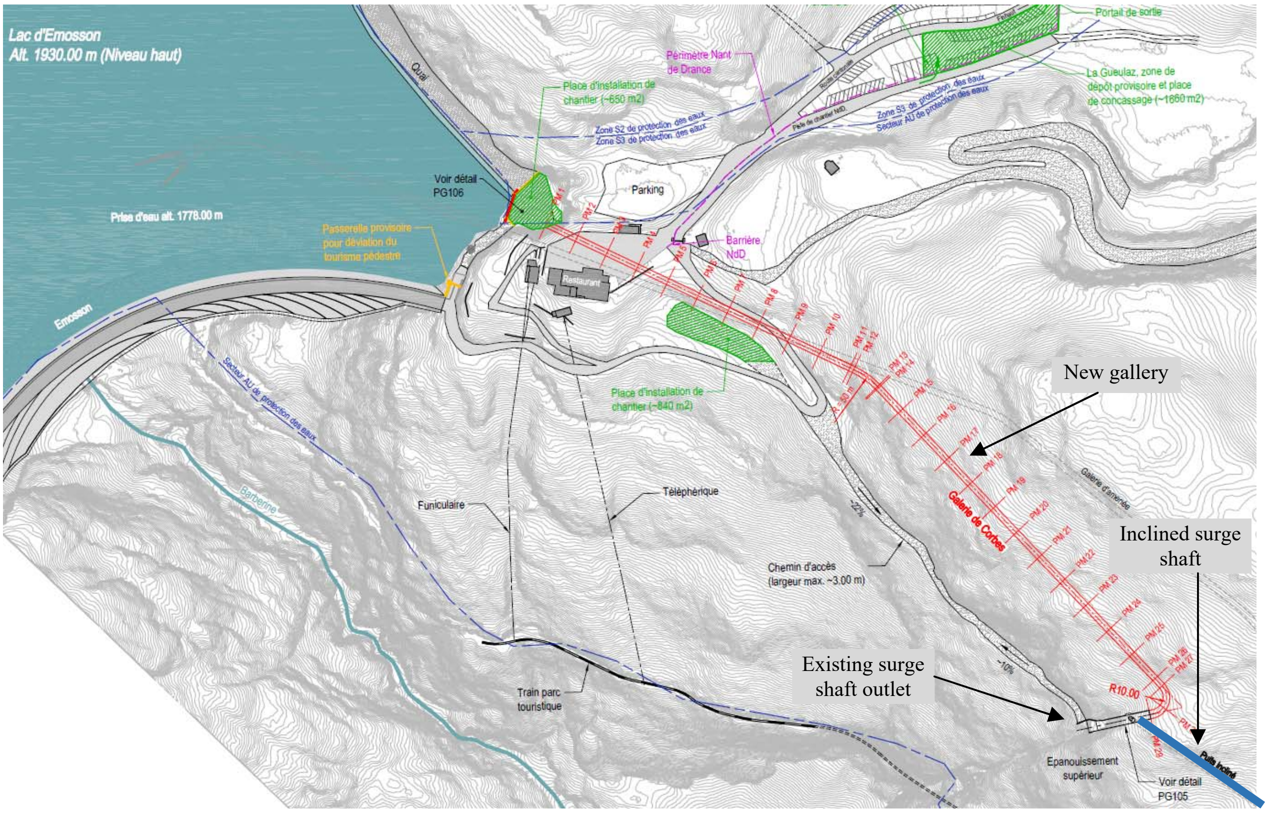

Fig. 2. Plan view of the new gallery (in red)

3. Hydraulic design

A new concrete wall has been erected between the top of the surge shaft and the water outlet in case of overflow of the surge shaft, deviating water to the new gallery. With a 1.6% slope, the new gallery will have a free surface flow towards the Emosson reservoir. An air inlet was designed to bring air from outside through the new wall and improve the hydraulic conditions of the free surface flow, see Figure 3.

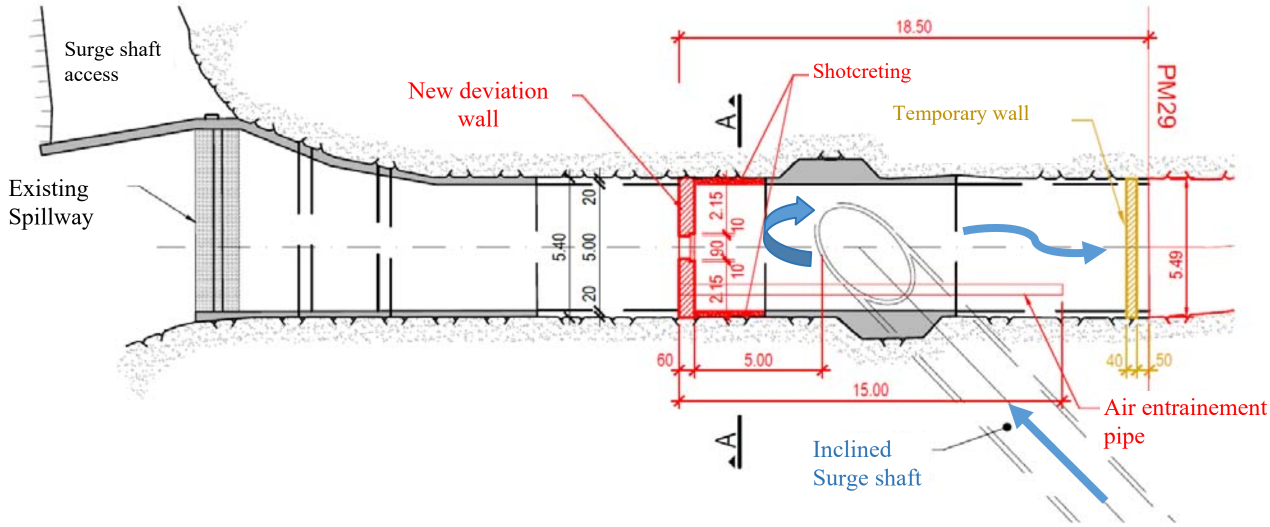

Fig. 3. View plan of the surge shaft with the new wall deviating water to the new gallery

The water pressure over the new wall and the flow conditions in the new gallery were estimated by the analytical methods and confirmed by a CFD analysis. Depending on the initial conditions and the water velocity in the surge shaft the pressure exerted on the wall would significantly vary.

The importance of air entrainment was highlighted in order to ensure free flow condition in the gallery by comparing single-phase (Flow 3D) and two-phase (Ansys-Fluent) codes. Sensitivity analysis was performed to study the effect of gallery surface roughness. The transient conditions last for about 10 minutes before reaching steady state flow condition and get full flow discharge at the end of the gallery. Figure 4 shows the evolution of the flow conditions in the surge chamber for the maximum flow discharge of 40 m^3/s.

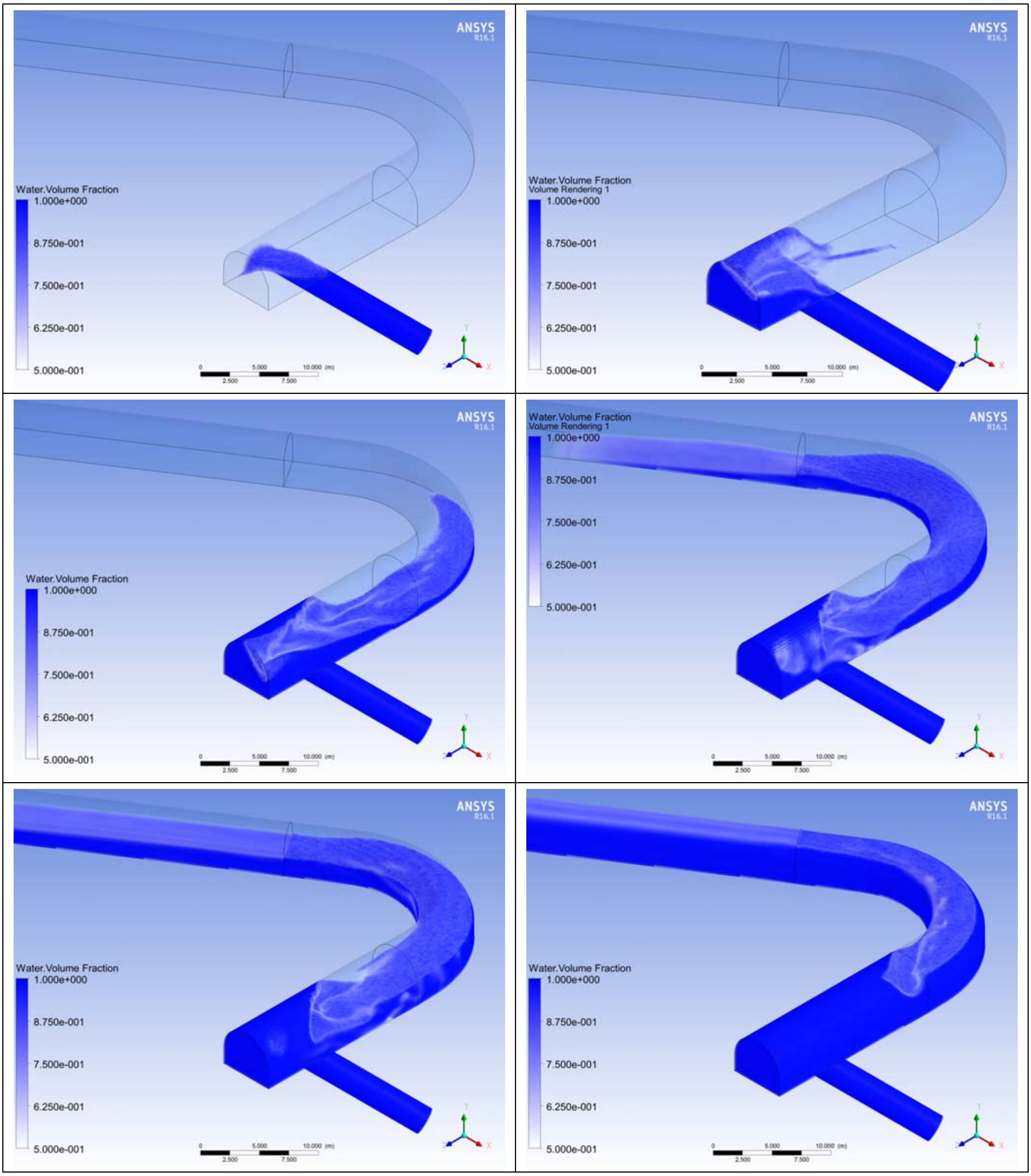

Fig. 4. 3D CFD modelling for 40 m^3/s overflow discharge

4. Site conditions

The execution of the new so-called "Corbes" Gallery took place in challenging alpine conditions, at an altitude of about 2000 masl. Due to a short execution window, works began early spring 2015, requiring the removal of massive amount of snow and managing spontaneous snowfalls.

The unstable cliff all along the access path to the chamber as well as above the gallery portal had first to be purged before considering any further works. The heavy rainfall during the spring season as well as vibrations effect due to the gallery blasting enhanced the risk of potential rock fall. In order to monitor potential cracks, and thus, rocks movements in the cliff cement patches were installed. Visual inspection of the cliff was performed after each blasting during the whole excavation phase, and particular attention was paid after every rainfall.

The construction of the temporary wall in the chamber had to be carried out in a 10-days window, while the pump stations were shut downed during daytime. However, heavy rainfall during this period filled up the downstream compensation basins, which had to be emptied through pumping water to the Emosson Lake. Due to the risk scenario of an upstream valve malfunction and consequently the overflow in the surge shaft, the construction site in the chamber had thus to be evacuated twice.

The excavation took place in hard and abrasive gneiss over 130 m and granites over 360 m crossing two faults Golette (F1) and F2, which had been recognised 40 years earlier, during the construction of the main spillway of the Emosson dam. Thus, three excavation profiles had been defined, see Figure 5, which mostly had to guaranty the safety of the workers. The site is close to the S3 zone in the classification of drinking water protection. The gallery layout had to be adapted to avoid crossing this zone.

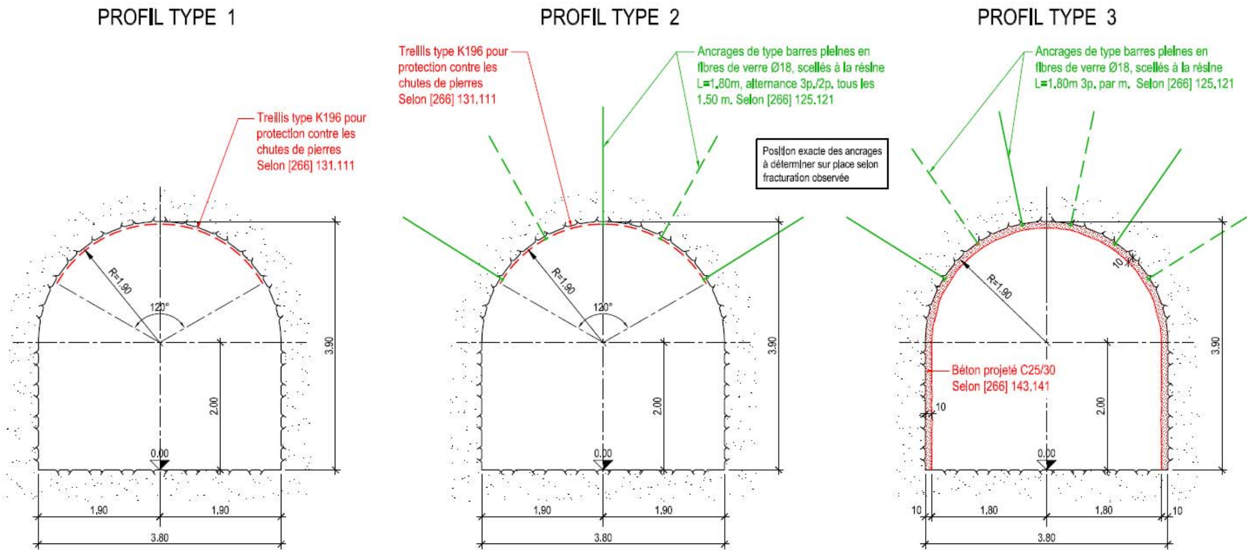

Fig. 5. Different class of gallery support system

The very good geological conditions allowed the use of the profile No. 1 for almost 75% of the gallery length. This enabled up to three drill and blast cycles per day, and resulting in an advancement rate of 10 meters per day. The high abrasivity of the rock however caused higher consumption of time and drilling material than expected. Local veins of soft ground material appeared to complicate the drilling and charging activities as the drilling holes tend to collapse before being able to charge them.

As the drill and blast excavation took place close to the existing Emosson dam as well as to other surrounding infrastructures, the effects of the vibrations on those were continuously monitored. Geophones were installed on the most critical places and alarm criterions were fixed as follows; 10cmm/s^2 for the dam, 15 mm/s^2 for the infrastructures and 20 mm/s^2 for the cliff. While these values where never reached during the excavation, the geophones enabled to monitor the effect of the vibrations within different distances while the excavation front was progressing.

As this region of Switzerland is known to have natural radioactive geological formations, particular attention was paid to this issue. Radioactivity was measured at the excavation front after each blasting, and miners were equipped with personal dosimeters.

As the site of Emosson is known for its great view and trekking possibilities, it attracts many visitors from May to September. Particular attention was thus paid to minimise the impact on the touristic attractions such as the funicular, the little train and the close by restaurant. As the access path to the dam crest led through the construction site, a provisory pedestrian bridge had been installed, in order to completely separate the site traffic from the pedestrians.

The excavation ended according to the schedule in mid-September 2015, with no light at the end of the tunnel, but the back face of the temporary wall. By the time the site installations were dismantled, the snow was back again.

The activities of 2016 ran on a similar schedule than those of 2015. A 10-day window was given to demolish the temporary wall and to build the permanent wall, which connects the new gallery to the surge shaft. In some altered zones, additional shotcreting works had to be carried out to guaranty the long-term behaviour of the gallery.

5. Conclusions

The Emosson scheme has a complex hydraulic configuration with interconnection of several reservoirs, hydraulic galleries, powerhouses and pump stations in the Swiss-French Alps. Part of these installations is also owned and operated by Swiss Federal railways. Due to this complexity and high risk in case of the surge shaft overflow for the tourism and downstream zone, different solutions were studied to improve the safety of the scheme. Among different solutions, a new gallery connecting the top of the surge shaft to the Emosson reservoir was found to be the best solution based on a multi-criteria analysis. The main purpose of the Corbes gallery is bring the water overflowing the surge shaft back to the Emosson reservoir.

The execution of the new Gallery took place in challenging alpine conditions in a very tight schedule with high surveillance of the pumping protocols. Complicated access, heavy rainfall and an unstable cliff just above the site with the risk of rock fall were the main difficulties in this first operation. As this region is a touristic highlight during summertime, great attention was paid in order to minimize any disturbance on the neighboring touristic installations.

The excavation of the gallery was carried out from May to September 2015. The final sealing wall and finishing works were conducted in summer 2016 following a tight day-by-day schedule to avoid the operation interruption as much as possible, while guaranteeing the safety of the workers. The work was successfully finished in mid-June 2016. An overflow test was performed to check good functioning of all safety alarms and to confirm the hydraulic conditions, see Figure 6.

Fig. 6. Overflow test with 5 m^3/s discharge

The Authors

Nima Nilipour, Civil Engineer, M.Sc. graduated in 2001 from Iran University of Science and Technology in Geotechnical Engineering. In 2003 he obtained his M.Sc. in Hydraulic schemes at Swiss Federal Institute of Technology in Lausanne (EPFL) and since then has been working in the design and construction of several hydropower schemes in Switzerland and abroad. In 2009 he joined BG Consulting Engineers and in parallel, he obtained his MBA in 2010 from HEC Lausanne. He is currently in charge of the Hydropower Unit of the BG Group.

Patrick Monnay, Mechanical Engineer, graduated from Ecole des Métiers de Lausanne in 1989. He is in charge of maintenance of Emosson scheme since 2013. Previously he was chief operation of powerplant and in charge of Mechanical team in Emosson. He is project manager of Corbes Gallery.

Michel-Jan van Mark, Civil Engineer, M.Sc. graduated in 2011 in Civil Engineering from Swiss Federal Institute of Technology in Lausanne (EPFL). Since he joined BG Consulting Engineers, he has been participating in the design and site supervision of different projects in Switzerland, particularly road infrastructure and underground hydropower projects. He was in charge of the site supervision of the Corbes Gallery.

Azin Amini, Civil Engineer, Ph D. graduated in Civil/Structural Engineering from University of Tehran, Iran, in 2002. She started her carrier as a structural engineer in Mahab Ghodss Consulting Company in Iran. She obtained her PhD degree in hydraulic engineering in 2008 from Ecole Polytechnique Fédérale de Lausanne (EPFL). Then she worked as a postdoc at Stanford University. She has academic and industrial experience in structural engineering, computational fluid dynamics and sediment transport studies. She has been involved in analysis and design of several coastal/river hydraulics and reservoir management projects worldwide. Currently she works as senior research assistant at laboratory oh Hydraulic Constructions at EPFL.